OPTICAL TRANSMISSION SYSTEMS INCLUDING OPTICAL COMPONENTS AND OPTICAL FILTERS AND METHODS OF USE THEREIN

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Not Applicable

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not Applicable

BACKGROUND OF THE INVENTION

[0003] The present invention is directed generally to optical systems. More particularly, the invention relates to optical WDM systems and optical components employing Mach-Zehnder filters, and methods of making and using such filters therein.

[0004] The continued growth in traditional communications systems and the emergence of the Internet as a means for accessing data has accelerated demand for high capacity communications networks. Telecommunications service providers, in particular, have looked to wavelength division multiplexing (WDM) to increase the capacity of their existing systems to meet the increasing demand.

[0005] In WDM transmission systems, information is transmitted using pluralities of electromagnetic waves at distinct wavelengths, or information carrying wavelengths, in the optical spectrum, typically in the infrared wavelength range. Each information carrying wavelength can carry a single data stream or multiple data stream that are electrically or optically time division multiplexed ("TDM") together into a TDM data stream.

[0006] The pluralities of information carrying wavelengths are combined into a multiple wavelength, "WDM", optical signal that is transmitted in a single waveguide. In this manner, WDM systems can increase the transmission capacity of existing space division multiplexed ("SDM"), i.e., single channel, systems by a factor equal to the number of wavelengths used in the WDM system.

[0007] One difficulty that exists with WDM systems is that the various signal wavelengths often have to be separated for routing/switching during transmission and/or reception at the signal destination. In early WDM systems, the wavelength spacing was limited, in part, by the ability to effectively separate wavelengths from the WDM signal at the receiver. Most optical filters in early WDM systems employed wide pass band filters, which effectively set the minimum spacing of the wavelengths in the WDM system.

[0008] Various tunable or fixed, high, low, or band pass or stop, transmissive or reflective filters, such as Bragg gratings, Fabry-Perot, Mach-Zehnder, and dichroic filters, etc. have been developed to address the need to separate wavelengths in WDM systems. These filters are deployed alone or in combination with various optical combiners and distributors, such as passive or WDM couplers/splitters, arrayed waveguides, circulators, dichroic devices, prisms, diffraction gratings, etc., as well as with isolators in various components and systems depending upon the desired application. The filters, combiners, distributors, and isolators can be deployed in various configurations, such as in one or more serial or parallel stages incorporating various devices to multiplex, demultiplex, and multicast signal wavelengths.

[0009] Many filtering devices, such as Mach-Zehnder, Fabry-Perot, arrayed waveguides, etc., have a periodic transmission properties that can be used to perform a filter function. The applicability of these filters depends upon the transmission properties associated with the filter function. For example, the ability of the filter to separate adjacent channels, thereby providing channel isolation and limiting crosstalk between the channels in the separation process will dictate the applications for which the filters are suitable.

[0010] Numerous variations of these filters have been developed in an attempt to improve transmission properties, such as channel isolation and crosstalk. For example, U.S. Pat. Nos. 3,936,144, 4,900,119, 5,309,534, 5,719,976, 5,978,114, and 5,946,432, all discloses various embodiments of Mach-Zehnder filters alone or in combination with other filters, such as Bragg gratings.

[0011] The continuing interest in developing new filters with improved filtering characteristics is based on the recognition that wavelength separation technology still poses a limitation to the development of higher performance, lower cost communication systems. As such, there is a need to improve continually the optical filters and filtering methods available for use in optical components, subsystems and systems.

BRIEF SUMMARY OF THE INVENTION

[0012] The apparatuses and methods of the present invention address the above need for improved optical transmission systems and optical filters for use therein. Optical transmission systems of the present invention include at least one double pass Mach Zehnder ("DPMZ") filter, which may be used in various applications within the system.

[0013] The double pass Mach-Zehnder filter includes a first optical coupling section coupling at least one input/output port to a first end of two or more optical communication paths, or Mach-Zehnder legs, having different effective lengths. A second optical coupling section is provided to couple at least one output/input port to a second end of the optical communication paths. The first and second optical coupling sections and two of the communication paths form a Mach-Zehnder interferometer. The double pass Mach-Zehnder filter is configured such that the output from at least one of the output/input port is coupled back into one of the one output/input ports and passes through the Mach-Zehnder interferometer a second time.

[0014] The difference in the Mach-Zehnder legs introduces a path length mismatch such that optical energy coupled to the input/output ports is coupled to at least one of the first and second output/input port according to a desired filter function. The first and second output/input ports are coupled such that optical energy exiting at least one of the output/input ports is provided as an input to at least one the output/input ports. Optical energy that enters the output/input ports passes through the Mach-Zehnder interferometer and exits the filter via at least one of the input/output ports.

[0015] In various embodiments, an isolator, a circulator, or other wavelength or non-wavelength selective isolation and/or reflective device introduces optical energy exiting the